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VFR Heliport Obstacle-Rich Environments: Draft Test Plan

Brian M. Sawyer
Deborah J. Peisen
Eric H. Bolz
Systems Control Technology
Arlington VA 22209

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Letter Report

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16. Abstract

This is a draft test plan for evaluating the psychological impact of an obstacle-rich VFR heliport environment on pilot performance. This evaluation would use a visual flight simulation. included in this report are objectives and issues, simulator requirements, data collection methodology, and a test plan syllabus.

This is the second of several letter reports that were developed as part of the preparation for evaluating pilot performance during the approach to and the departure heliports in an obstacle-rich environment. The other reports are:

(1) FAA/RD-94/41, VFR Heliport Obstacle-Rich Environments: Test and Evaluation
(2) FAA/RD-94/43, VFR Heliport Obstacle-Rich Environments: Simulation Requirements and Facilities

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1.0 INTRODUCTION

This is a draft test plan developed to apply the test requirements necessary to evaluate pilot performance when helicopters are operated at heliports with environments of varying obstacle density. The initial letter report provided test scenarios, evaluation methods, data processing techniques, and government/industry comments concerning pilot performance in an obstacle-rich environment. A second letter report detailed the issues and concerns connected with using visual flight simulation for evaluating pilot performance and developing target levels of safety in an obstacle-rich environment. That report emphasized assessing existing state-of-the-art helicopter simulators with regard to capabilities, limitations, availability, and basic user cost. The addition of a generic draft test plan provides the FAA with a tool to evaluate the simulation requirements necessary to assess pilot performance, perception, and target levels of safety.

This draft test plan outlines the methodology used in the letter reports to provide a clear understanding of the scope and objectives needed to perform the simulation. Using an "approach procedure model," both real and abstract heliport models can be generated to test a pilot's ability to perform in an increasingly obstacle-rich heliport environment. Each flight regime will be evaluated, including scenarios that address ground-to-air and air-to-ground requirements. Resultant data will be used to assess performance factors and associated levels of safety within each of the specified flight regimes. Final simulation results will be provided to the FAA for verification through actual aircraft flight testing.

The overall project is divided into two phases. Phase one establishes simulation requirements and assesses facility availability. Phase two focuses on the application and analysis of phase one criteria to develop the actual simulation test. The following separate subtasks form the core of phase one:

1. test and evaluation requirements,
2. simulation requirements and facilities,
3. simulation test plan, and
4. pilot briefing materials.

Thorough examination of the results of subtasks 1 and 2 have produced the foundation for test plan development. To supplement the test plan, subtask 4 provides pilot briefing materials that explain the pilot's role and participation in the test program.

1.1 PURPOSE

This test plan is designed to profile the chain of events necessary to evaluate pilot performance using a piloted visual flight simulator in a VFR heliport obstacle-rich environment. Using the simulation variables defined in the initial report, "VFR Heliport Obstacle-Rich Environments Test and Evaluation," and the simulation requirements of the second report, "VFR Heliport Obstacle-Rich Environment Simulation

Requirements and Facilities," a model plan will be formulated for visual scenario development and optimal simulator effectiveness.

1.2 STRUCTURE

To sustain a smooth transition between test specifications and simulation requirements, each criterion identified within the test plan must be carefully weighed and matched against current simulation technology. Comprehensive simulation modeling that will duplicate task scenarios within acceptable levels of fidelity will be carefully examined. Development of each facet of the test plan must appropriately address the necessary tier of simulation complexity.

To provide the FAA with an assessment of the most cost-effective simulation facilities, the information gathered from the "IFR Visual Segment Evaluation Test Plan" was used as the nucleus for this test plan. Numerous reviews and on-site evaluations were conducted during the developmental stage of the IFR test plan to identify suitable simulation facilities. Both projects' simulator specifications, "The Obstacle-Rich Environment Assessment," and the "IFR Visual Segment Evaluation" have similar test requirements. Both have a visual scene condition as the common core which establishes the basic simulation requirements:

- o fidelity of object recognition,
- o orientation capability and ability to align for arrival or departure, and
- o vehicle flight handling qualities.

1.3 BACKGROUND

The evolution of simulation technology offers engineers a tool with qualities that will closely duplicate actual aircraft in any flight regime. The advancement of rotorcraft simulation has accelerated over the past decade. Most simulation facilities have unique engineering capabilities with specialized hardware and software that maintain control of evaluation test parameters. They provide a complete service, including the system and skilled personnel to modify or develop the simulation to satisfy test requirements.

2.0 OBJECTIVES AND ISSUES

2.1 OBJECTIVES

The objective of the proposed test plan is to develop a method for qualifying and quantifying pilot performance in an obstacle-rich environment. Using human factors engineering techniques, the true man/machine interface (MMI) can be explored. Execution of designated pilotage tasks will provide a weighted workload versus overload assessment of performance. The test results will assist aviation planners. Development and enhancement programs at urban heliports and airports, influenced by nearby obstacles, will be able to control and

manage the impact of those obstacles on their facility. The principal distinction between current and future aerodrome operations planning will be the application of these results. By applying a weighted factor to visual obstacle clearance criteria within the takeoff and landing area of a heliport or airport, minimal operational interference can be accomplished. This methodology provides the best solution to dense obstacle-rich environments.

The ability of the helicopter/pilot combination to maneuver under visual conditions is well understood and helicopter performance during various takeoff and landing modes is well defined. The transition to the heliport under varying obstacle density has not been quantified. This established the need for conducting the simulator evaluation described in this test plan.

The effect that obstacles have on a helicopter pilot's capability to maneuver the helicopter may impact heliport design and operations in several ways.

- Applying visual approach clear zone dimensions and/or visual obstruction clearance requirements can strongly influence the treatment of obstacles and the protected airspace requirements of a heliport. In addition, recognition of well-defined arrival and departure corridors within the heliport VFR imaginary surfaces could strongly influence minimum acceptable levels of obstacle density.

- The visual cues within the obstacle-rich environment preceding the actual landing or departure may prove to be insufficient for the pilot to execute the procedure. This may influence the effects of close-in obstacles on protected airspace requirements and result in unacceptable levels of safety.

- The ability to see and avoid obstacles while evaluating their effect on pilot performance, perception, and safety remains to be seen. Effects on minimum protected airspace requirements could be illustrated.

The absence of well-defined simulation procedures and techniques for measuring human factors initiatives provides an excellent opportunity to explore innovative techniques for assessing pilot performance. Preliminary indications support that current methods for designing or revising protected heliport airspace requires new definition. These new procedural assessments will bring into focus a series of technical and operational issues dealing with pilot performance that must be resolved. Applying test results to "in-use" VFR urban heliports could have the consequence whereby pilot proficiency or operational standards may be required to operate at a specific location. Current takeoff and landing paths in and out of VFR facilities in an obstacle-rich environment could exceed these performance standards, thereby rendering a heliport an operational hazard. Applying these "new" performance standards to in-use facilities would increase the level of

difficulty when considering certification requirements. Clarification will require a site-by-site assessment to find an appropriate resolution for each facility. A secondary objective of the overall evaluation is application to in-use facilities. Using real heliport models as part of the simulation study will generate a preliminary baseline to apply these measures to "actual" heliports.

The major objective of this test plan is to determine what effect an obstacle-rich environment has on pilot performance, perception, and safety. The helicopter pilot's ability to maneuver the aircraft in an obstacle-rich environment significantly affects cockpit workload. These simulator tests are designed to determine the limits to which helicopter pilots may be expected to:

- become (and remain) oriented under varying atmospheric and visual conditions within the heliport environment or transversing the arrival or departure corridors,
- reliably see and avoid obstacles underneath the visual approach/departure corridor leading up to and away from the heliport, and
- take advantage of human factors techniques to determine effects of obstacle density.

2.2 ISSUES TO BE EVALUATED

The issues associated with this undertaking are in five basic, interrelated simulation areas: visibility, airspace dimensions, helicopter maneuverability, psychological effects, and safety. There are specific problem areas associated with each of these issues.

2.2.1 Visibility

These issues relate to the pilot's ability to become and remain visually oriented while transitioning from an arrival or departure pattern.

2.2.1.1 Object Visibility

How readily visible to the pilot are the various categories of terrain features and obstacles in an urban environment? Are there distinct and measurable differences in the ability to perceive terrain features, buildings, bridges, towers, poles, wires, helipad markings and lights, and various lighted and unlighted structures?

2.2.1.2 Approach Speed

How does helicopter approach speed affect the pilot's ability to discern obstructions and/or landmarks in sufficient time to take appropriate action at various visibility levels?

2.2.1.3 Orientation/Situational Awareness

How much familiarity, obstruction/landmark recognition, area definition, etc., is required for the pilot to be certain he/she will be able to remain within the protected VFR imaginary surfaces provided for the approach or departure?

2.2.1.4 Familiarity

What effect does familiarity have on reduced visibility limits for the approach/departure?

2.2.2 Airspace Dimensional

These issues relate various factors to the protected airspace dimensions that must be allocated to assure a safe procedure for all authorized users.

2.2.2.1 Object Visibility

What are the impacts of variations in object visibility and discernability on the minimum required dimensions of the visual orientation zone (at varying visibility levels)?

2.2.2.2 Familiarization Aids

How do factors such as improved charting, area familiarization, distinctively painted/lighted structures and beacons, and helipad marking/lighting affect protected airspace dimensions?

2.2.2.3 Maneuvering Speed/Airspace

Do reductions to maneuvering speeds, while navigating within the visual segment, affect protected airspace dimensions?

2.2.2.4 Transition Airspace

How much area must be protected to allow lateral transition through the heliport environment during arrival or departure?

2.2.3 Helicopter Maneuverability

These issues are directly related to the pilot's ability to maneuver the helicopter as intended.

2.2.3.1 Course Acquisition

How quickly will the pilot be able to capture the intended visual course (e.g., heliport environment) once it is visually identified? What aids will help?

2.2.3.2 Maneuvering Speed

To what extent does reduced speed enhance maneuverability and at what speed, if any, does control become a problem?

2.2.3.3 Maneuverability

How quickly or safely can the pilot maneuver to avoid obstacles within the visual approach/departure corridor?

2.2.4 Psychological Effect on Pilot Response and Performance

The test plan will answer some basic pilot performance questions about the number, type, and placement of obstacles found below the VFR heliport imaginary surfaces. Does obstacle density create a psychological consequence that outweighs the desirability of a heliport location?

2.2.4.1 Risk Assessment for Pilot Decisions

Flight near heliports presents a certain level of risk in striking obstacles. Can a potential risk assessment factor be assigned to a pilot's decision that would yield a numerical weighted value for analysis?

2.2.4.2 Obstacle Perception Factor

Each pilot mentally allocates a level of intimidation to the potential hazard that an obstacle may present. Consequently, there is a supplemental factor that must be considered when rating obstacles of different texture and/or consistency and their potential effect on a pilot's perception.

2.2.5 Target Level of Safety

Safety introduces the need for analytical quantification of obstacles affecting pilot performance to generate a fundamental "target level of safety (TLOS)." A TLOS provides an objective way to measure and manage safety.

A level of safety needs to be established regarding the number and proximity of obstacles near a VFR heliport so that potential psychological effects on pilot performance can be minimized.

2.2.5.1 Risk Factor for Obstacle Density

No specific evaluation process has been designed to test obstacle density under the VFR imaginary surfaces from a perceptual basis. Can the perception of the potential risk of individual obstacles be measured by type, location, height, and intensity to yield a numerical value?

2.2.5.2 Risk Factor For Close-In Obstacle Perception

The appearance of close-in obstacles, as determined by their relative distance and position in the immediate landing and takeoff area, provides a true perspective of the overall obstacle scene. Limitations of visual cues within the surrounding field-of-view may adversely affect a pilot's ability to assess an appropriate level of avoidance. The design and development of the various scenarios for the test must represent the potential significance of close-in obstacles.

2.3 SIMULATION OBJECTIVES AND SCOPE

To arrive at a productive test syllabus, the specific objectives of the simulation effort must be defined.

2.3.1 Visibility and Object Recognition

The objectives are to ascertain the pilot's ability to visually discriminate and recognize various classes of objects and obstacles under varying visibility conditions. This includes evaluation of various types of objects (terrain, buildings, towers, bridges, etc.), the heliport and its environment, and lighting aids and other visual cues under measured reduced visibility conditions.

2.3.2 Orientation and Alignment

Given appropriately designed/defined approach and departure environments, the ability of the pilot to become quickly oriented in the operational environment must be evaluated. This is critical where considerable alignment maneuvering may be required because the heliport or departure corridor does not lie straight ahead. This objective includes evaluation of all candidate techniques for orientation enhancement, including specialized charting improvements, specialized landing aids, and/or familiarization training.

2.3.3 Maneuvering and Control

This objective includes quantifying pilot and aircraft performance to provide the heliport developer with an explanation of the methodology used for determining the airspace to be protected for rotorcraft when maneuvering to the visual approach/departure corridor or transitioning to the heliport. These determinations must consider the entire range of possible positions both inside and outside the 95 percent probability corridor. Also included is the need to evaluate the minimum maneuvering speeds for which the helicopter is certificated and at which the pilot feels comfortable in visual corridors.

2.3.4 Pilot Performance and Perception

The basic assumption is that pilot performance and perception or "workload" is affected by a variation in the density of obstacles. It

is evident that an "overload" will occur at some point based on task complexity and difficulty. The objective is to induce conditions of overload through simulation that hampers performance capability. Rating scales based on the 1969 Cooper and Harper evaluations will provide an appraisal of the simulator events.

Currently, the scope of the simulation study is limited to the collection of data only, with analysis of that data to be accomplished in later tasks. The intent is to collect sufficient data to provide statistically significant results in each of the four above-mentioned areas so they may be used as the basis for developing appropriate weighted measures in an obstacle-rich environment.

3.0 APPROACH PROCEDURE MODEL

Two types of approach procedure models are to be evaluated during these simulation studies:

- o real model, in which actual urban heliport environments are re-created with actual approach/departure corridors, facilities, and charting; and
- o abstract model, in which a variety of variables may be selected, either as modifications to a real environment or to an environment created specifically for the evaluation, or both.

The re-creation of real environments will provide an important link to actual operational experience for validation of the results, as well as a test bed for evaluating alternatives pertinent to those environments. The abstract model will be important for providing the ability to evaluate issues of interest specific to this study. Complexity of the evaluation and the number of variables must be explored. A motif queue of three core prototype patterns will be needed to create as many as 30 scenarios. These scenarios will include visibility, airspace dimensions, obstacle avoidance capability/techniques (maneuverability), psychological effects and safety. The processing flow chart for each model is shown in figure 1.

3.1 REAL MODEL

The proposed real model is based on two urban heliports that are in common use today. The first set is to be based on the Indianapolis Downtown Heliport that is located on irregular, uneven terrain in an area with only a few significant obstructions to flight or visibility. A second set would involve the Wall Street Heliport that is located on a specially built pier in the East River near numerous tall buildings, a series of bridges, and constant harbor vessel traffic. While the Wall Street location is far more problematic operationally, the local pilot population is accustomed to operating in that environment.

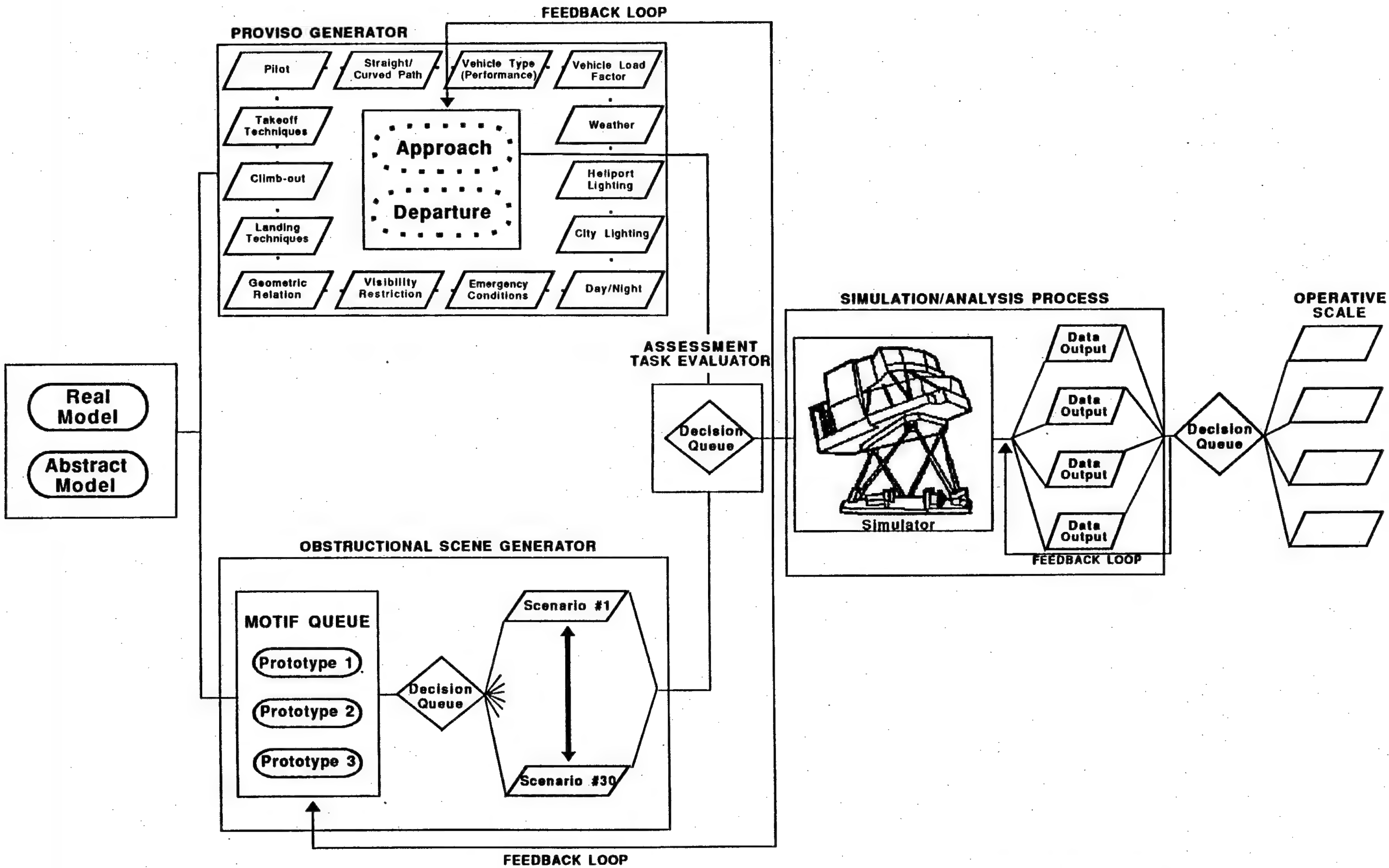


FIGURE 1 MODEL PROCESSING FLOWCHART

Each of these locations presents a different set of issues to be addressed. In Indianapolis, where the best approach direction is from the southwest (because of obstacles), the approach/departure corridors interfere with departure traffic from the city's nearby commercial airport. An easterly approach or departure satisfies the air traffic control problem. Unfortunately, it involves negotiating close-in obstacles which reduce heliport operability.

The Wall Street Heliport also presents a variety of additional problems associated with helicopter capability and pilot performance: slow speed requirements, minimum turn radius for arrival and departure, steep descent and climb gradients, and a highly obstructed environment.

3.2 ABSTRACT MODEL

The abstract model, which may be based on an actual or generic heliport environment, is intended to provide the variety of operational variables needed to evaluate the relevant issues. To accomplish this, the following features must be generated and be at the command of the simulator operator:

- a complete urban model with buildings, highways, rivers, natural terrain features, and major landmarks such as sports stadiums, etc.;
- a heliport and landing environment appropriate to the urban environment, created with minimum size, marking, lighting, etc.;
- current and experimental charting;
- a set of candidate heliport and visual lighting options;
- a pool of selectable obstacles (including buildings, towers, and terrain features) designed to control or infringe on the VFR heliport imaginary surfaces to varying degrees, from anywhere in the arrival or departure corridor;
- a pool of landmarks suitable for evaluating pilot ability to identify the pre-landing zone environment, and/or to serve in providing visual guidance to the landing zone; and
- a standardized set of reduced visibility levels to be created by the simulator visual subsystem.

4.0 SIMULATOR REQUIREMENTS

4.1 SIMULATION FEASIBILITY

State-of-the-art simulation technology has resulted in a variety of applications for both rotary- and fixed-wing aircraft. The main

consideration is achieving the desired fidelity for the specific simulation initiative being evaluated. Achieving simulation that emulates the required variables is paramount. Any simulation must qualify and quantify all necessary aspects of the flight test regime. The characteristics described in the following paragraphs are the minimum conditions a simulation candidate must emulate to verify a procedure.

4.2 SIMULATION CHARACTERISTICS

4.2.1 Rotorcraft Handling Qualities and Dynamics

The difficulty in designing helicopter simulation models increases proportionately with the complexity of components and modules represented.

4.2.1.1 Dynamics

A single-engine helicopter model that accurately portrays actual aircraft characteristics over the full range of flight regimes must be used in this simulator investigation. The degree of sophistication required of these models clearly depends upon the flight performance characteristics to be simulated. Looking only at the VFR flight segment allows specific simulation parameters to be refined.

4.2.1.2 Handling Qualities

To stay within the parameters of this task, the qualities addressed in the following paragraphs must be established in a simulation rotorcraft model.

<u>Responsiveness</u> - The simulator must respond properly to changes in attitude, altitude, temperature, gross weight, center of gravity, configuration, and ground effect.

<u>Control Forces</u> - The control forces and degree of travel must accurately represent the helicopter being modeled. If a generic helicopter is modeled, the control forces must represent similar helicopters in the same performance class.

<u>Response to External Influence</u> - The simulator must be capable of providing representative modeling of crosswind, wind shear, and air wake effects caused by terrain, buildings, etc.

<u>Response Rates</u> - The simulator must demonstrate acceptable and consistent response rates as reflected in the cockpit instrumentation, visual, and motion systems (if provided).

4.2.2 Visual Aids

In the heliport environment, visual aids provide course accuracy by supplying cues to the pilot for estimating his/her position in

relation to the heliport. Visual systems are not perfect and do not provide true position relative to the earth. For simulation, visual aids must represent the operating and error characteristics of the particular system used when executing arrival or departure procedures from a heliport.

4.2.3 Cockpit Instrumentation

4.2.3.1 Instrument Capability

The simulator must provide sufficient instrumentation to support the execution of both arrival and departure procedures.

4.2.3.2 Navigation and Communication Equipment

The simulator must have navigation and communication capabilities that would support normal VFR operations and require normal cockpit interface. The navigation equipment must have operational and accuracy characteristics representative of the functions and performance capabilities of simulated systems.

4.2.3.3 Performance Instrumentation

The simulator must possess performance instrumentation (engine, transmission, torque, etc.) that would require normal cockpit attention.

4.2.3.4 Instrument Response

Instrument response must correlate to the rate of change and displacement of controls of the helicopter being modeled. If a generic helicopter is being modeled, the response must be typical of similar single-engine helicopters in the same performance class. Instrument response must be closely coupled to the visual system.

4.2.4 Environmental Disturbances

The simulator must be capable of emulating the ceiling and visibility conditions associated with a visual approach or departure. This must include varying weather phenomena such as changes in wind direction and velocity, precipitation, haze, and smoke.

4.2.5 Visual Scene Response

The visual reproduction must emulate various conditions necessary to validate the test initiatives. The parameters described in the following paragraphs are a minimum.

4.2.5.1 Visual Scene Quality

Visual scene quality and the ability to accurately depict reduced visibility are the foremost considerations for this evaluation.

4.2.5.2 Visual Scene Response Time (Transport Lag)

The visual scene must respond to abrupt pitch, roll, and yaw at the pilot's position within 100 milliseconds of the time when the helicopter would respond under the same conditions.

4.2.5.3 Resolution

The simulator must be capable of depicting a variety of obstructions with sufficient resolution (3 arc minutes or better at the pilot's eye) to support detection, identification, and avoidance capability in accurately presented, reduced visibility models.

4.2.5.4 Field of View

The nature of this evaluation requires a minimum field of view of 90 degrees (150 degrees preferred) horizontal and ± 20 degrees (± 40 preferred) vertical.

4.2.5.5 Day, Night, Dusk

The simulation will require evaluation during day, night, and dusk operations. Buildings and other obstacles must be capable of being properly (realistically) lighted for dusk and night operations.

4.2.5.6 Depth Perception

The simulator must provide necessary visual cues to allow assessment of sink rates and sufficient depth perception for low altitude/low airspeed maneuvering, hover, and landing.

4.2.6 Motion and Sound Cues

Motion is desirable but not required for this evaluation. If motion is available, it must conform to actual aircraft response to external and internal inputs. It should exhibit characteristic buffet where applicable. The simulator must produce sounds corresponding in amplitude and frequency to sounds found in the represented cockpit.

4.2.7 Cockpit Viewing Angles

The pilot's viewing angles must represent the helicopter being modeled. If a generic helicopter is used, the viewing angles should represent helicopters in the same class. Unobtrusive visual shields representing cockpit structural members, glare shields, etc., may be used to block the pilot's vision where appropriate.

5.0 SIMULATION DATA COLLECTION METHODOLOGY

The following paragraphs describe the generic test conditions and the data elements to be recorded during the tests. These test conditions and data elements to be recorded will be developed in greater detail

during phase two of the test program when specific knowledge of the simulation facility is known.

5.1 SIMULATOR VARIABLES AND TEST MATRIX

This section recommends simulator variables that will be used in developing the simulation test plan. Specific scenario design should concentrate on the following elements:

- visibility,
- terrain types,
- type heliport/helipad,
- lighting options,
- airspeed,
- course orientation,
- obstacle/structures, and
- meteorological conditions.

Precise scenario modeling requires further conditional statements when considering the abundance of obstacles and flight regimes. Designing the actual simulation demands a clear-cut organization of obstacles and the flight regimes into distinctive fields. The following are to be considered.

5.1.1 Obstacle Classes

When considering the number and type of obstacles associated with the simulation development the following category definitions will be applied:

- obstacles (below the VFR surface) - landmarks and visual cues used for orientation, navigation and flight progress monitoring,

- obstacles (below the VFR surface) - perceived as potential threats, and

- obstacles (above the VFR surface) - to be avoided.

Note: - Obstacles will not conform to or define the 8:1 VFR slope.

5.1.2 Flight Phases

The arrival and departure corridors can be considered a thoroughfare in the sky. To provide assurance that the appropriate aspect of flight is evaluated against a specific class of obstacle the succeeding classifications will utilized:

- Orientation Phase
  - visual (en route) to visual approach transition,
  - acquisition of approach course based on visual cues, and
  - obstacle avoidance in the transition areas.

- Arrival Phase
  - approach course already visually acquired,
  - cues use for navigation, speed and descent rate control, and
  - obstacle avoidance along approach course.

- Landing/Takeoff Phase
  - landing zone already visually acquired,
  - cues used for final descent and landing control,
  - cues used for takeoff and departure, and
  - obstacle avoidance in immediate heliport environment.

5.1.3 Issues in Relation to Obstacle Classes

The preliminary assessment of issues must be matched against the above obstacle classes and flight phases. This link provides the groundwork for scenario design and development when matched against distinct simulation variables.

o <u>obstacles/landmarks/cues</u>	<u>associated issues</u>
o orientation phase	2.2.1.1, 2.2.1.2, 2.2.1.3, 2.2.1.4, 2.2.3.1, 2.2.3.2., 2.2.4.2.
o arrival phase	2.2.1.1, 2.2.1.2, 2.2.1.3, 2.2.1.4, 2.2.3.2, 2.2.4.2.
o landing/takeoff	2.2.1.1, 2.2.1.2, 2.2.1.3, 2.2.1.4, 2.2.4.2, 2.2.5.2.
o <u>obstacles perceived as threats</u>	<u>associated issues</u>
o orientation phase	N/A
o arrival phase	2.2.4.1, 2.2.4.2, 2.2.5.1.
o landing/takeoff	2.2.5.2, 2.2.4.1, 2.2.4.2.
o <u>obstacles to be avoided</u>	<u>associated issues</u>
o orientation phase	2.2.1.1, 2.2.1.2, 2.2.1.3, 2.2.1.4, 2.2.3.3, 2.2.3.1, 2.2.3.2, 2.2.4.2.
o arrival phase	2.2.1.1, 2.2.1.2, 2.2.1.3, 2.2.1.4, 2.2.2.1, 2.2.2.2, 2.2.2.3, 2.2.2.4, 2.2.3.3, 2.2.3.2, 2.2.4.2.
o landing/takeoff	2.2.1.1, 2.2.1.2, 2.2.1.3, 2.2.1.4, 2.2.3.3, 2.2.3.2, 2.2.4.2, 2.2.5.2.

By categorizing test objectives with scenario variables, issues of perception, performance, and safety can be assessed. In the test plan, development scenarios and estimates of the number of simulator test runs required will be evaluated against all of the scenario variables. Two tables are presented for planning purposes. Table 1 categorizes the test objectives (a through j) and lists the variables that are to be evaluated in order to address each of the issues identified in section 2.2. Table 2 presents estimates of the number of simulator tests runs that will be required to evaluate all simulation variables.

The key to the number of runs and scenario development is the use of three prototype patterns. Each pattern is designed to provide a baseline on which to focus. This will maintain scenario integrity and control throughout test runs as variables are entered or removed from the individual scenes. Each will establish a foundation from which the real or abstract model can be generated. It is anticipated that somewhere within the range of a prototype pattern will exist a real heliport model. The abstract heliport models will be composed of addition (or deletion) and modification of features and obstacles pertinent to the specific test objectives (a through j).

Each of the test cases, a through j, will be examined to verify prototype pattern and model suitability. Using a real model will validate pilot performance, perception, and safety in a verifiable heliport environment. Real models are limited in scope and may not fully present the appropriate test scenario. Abstract models furnish that experimental influence necessary to probe variations in obstacle density.

Subject pilots will be teamed in small groups of three. Each pilot will perform the same number of runs on a given test. Tests will be sequenced randomly to prevent undue subject pilot familiarity with the simulated environment (except those for which familiarity is being specifically evaluated). One set of pilots may be used randomly for a variety of tests.

5.2 DATA COLLECTION PROCEDURES

Preparation for the data collection phase of the simulator evaluation will involve subject pilot selection, development of pilot briefing materials, and definition of the sequence of tests. This section discusses these areas, as well as the data collection methods and parameter lists.

TABLE 1
ISSUES AND SIMULATION VARIABLES

Objective	Sub-objective	Issue #	Issue name	Flight phase	Conditions	Scenarios
a. Visibility	Perception (object recognition and spatial orientation)	2.2.1.1 2.2.1.2 2.2.1.4	Object visibility Approach speed Familiarity	Orientation, arrival, landing and takeoff	-At night cross-country minimums (1000/3) -At day local minimums (500/1)	Terrain: rivers, hills Structures: buildings, towers, bridges, roadways, sports stadiums, construction crane Heliports: ground level, rooftop, airport, lighting options
b. Visibility	Protected Airspace (course alignment cues)	2.2.1.3 2.2.1.4 2.2.2.1	Orientation/situational awareness Familiarity Object visibility	Arrival, landing and takeoff	-At night cross-county minimums (1000/3) -Structure lighting/contrast variations -Beacons on structures -Heliport marking and lighting variations	From objective a
c. Orientation and alignment	Situational awareness	2.2.1.3 2.2.2.1 2.2.2.2	Orientation/situational awareness Object visibility Familiarization aids	Orientation, arrival	-From objectives a and b	From objective a
d. Orientation and alignment	Course alignment (protected airspace)	2.2.1.3 2.2.2.1 2.2.2.2 2.2.2.3 2.2.2.4	Orientation/situational awareness Object visibility Familiarization aids Maneuvering speed/airspace Transition airspace	Arrival	-Approach speeds variations -Transition path variations -Alignment cue variations	From objective a
e. Maneuver-ability	Course alignment (protected airspace)	2.2.1.2 2.2.2.3 2.2.3.1	Approach speed Maneuvering speed/airspace Course acquisition	Arrival, landing and takeoff	-Capture angle and offset variations -Alignment cue variations	From objective a
f. Maneuver-ability	Aircraft control	2.2.3.2	Maneuvering speed/maneuverability	Arrival, landing and takeoff	-Speed variations (at and below normal) -Capture angle and offset variations	From objective a
g. Maneuver-ability	Obstacle avoidance	2.2.1.2 2.2.2.3	Approach speed Maneuvering speed/airspace	Arrival, landing and takeoff		From objective a
h. Pilot performance	Risk assessment (Cooper-Harper)	2.2.4.1	Risk assessment for pilot decisions	Arrival, landing and takeoff	-Initial condition variations (easy to difficult	Various heliport types Various structures to avoid
i. Pilot performance	Close-in obstruction (Cooper-Harper)	2.2.4.2 2.2.5.1 2.2.5.2	Obstacle perception factor Risk factor for obstacle density Risk factor for close-in obstacle perception	Arrival, landing and takeoff	-Structure lighting/contrast variations	Structures at/near the obstruction surfaces
j. Pilot performance	Target level of safety	2.2.5.1 2.2.5.2	Risk factor for obstacle density Risk factor for close-in obstacle perception	Arrival, landing and takeoff	From objective i	Multiple structures with constant risk factor ratings

TABLE 2

ESTIMATE OF NUMBERS OF SIMULATION RUNS

Test	Calculation of Simulation Runs Required
a.	[2] Visibilities X ([2] Terrain cases + [6] Structure types + [3] Heliport types + [2] Lighting options) X [3] Pilots X [2] Repetitions = 156 runs, 11 scenarios maximum
b.	[1] Visibility X ([3] Structure Vis. variations + [2] Beacon cases + [4] Heliport Marking & Lighting variations) X [3] Pilots X [2] Repetitions = 54 runs, scenarios from 'a'
c.	Cases and Scenarios from 'a' and 'b'
d.	[3] Alignment Cue cases X ([3] Speed cases + [2] Transition cases) X [3] Pilots X [4] Repetitions = 180 runs, 3 new scenarios
e.	[3] Alignment Cue cases X [4] Course Capture & Offset cases X [3] Pilots X [2] Repetitions = 72 runs, scenarios from 'd'
f.	[3] At- and Below-Normal Speed cases X [4] Course Capture & Offset cases X [3] Pilots X [2] Repetitions = 72 runs, scenarios from 'd'
g.	[3] Structure classes X ([2] of Each Class + [2] Structure Vis. variations) X [3] Pilots X [4] Repetitions = 144 runs, scenarios from 'a'
h.	[2] Heliport Types X [3] Structure types X [4] Initial Conditions & Wrong Decision cases X [3] Pilots X [2] Repetitions = 144 runs, 6 new scenarios
i.	[2] Heliport types X [2] Structure types X ([2] Structure Vis. variations + [2] Distance/Height Profiles) X [3] Pilots X [2] Repetitions = 96 runs, 4 new scenarios
j.	[2] Heliport types X [3] Multiple Structure cases X [3] Pilots X [8] Repetitions = 144 runs, 6 new scenarios

Total = 1062 runs (maximum 30 scenarios)

Note: To produce the 30 scenarios, a minimum of three prototype patterns must be designed and developed to support the above-specified simulation runs:

Prototype 1: Hilly terrain, portion of major city and one ground-level urban heliport

Prototype 2: Even terrain with lake shore and river, major city with one ground-level urban heliport and one airport heliport

Prototype 3: Same environment as prototype 2 with one urban roof-top heliport

5.2.1 Subject Pilot Selection

Pilots selected for this study will include professional research pilots selected from the FAA and NASA, and professional commercial and private helicopter pilots, with emphasis on those who currently operate in an urban environment. Current research pilots, besides serving as an additional data source, will help interpret the performance of other subject pilots, assist with real-time evaluation of test parameters, make recommendations for program updates, and assist with any other required/desired program changes as data processing/analysis takes place. To maintain an appropriate level of integrity among pilot candidates, each will be separated into well-defined groups and categories. Group classifications will be associated with pilotage background (i.e., private, corporate, or research), while category divisions relate directly to proficiency (i.e., total time as pilot-in-command).

5.2.2 Pre-test Briefings

Before conducting any tests, participating pilots will be thoroughly briefed on the objectives of the test. The specific issues and concepts being evaluated will be discussed in detail. Charts and other materials developed for the tests will be presented for review.

5.2.3 Sequencing and Performance of Test Scenarios

A plan will be developed for the random sequence of simulator scenarios to be flown by each pilot. This plan will control the effect of learning on test results. This will prevent, for example, the pilot from knowing where to expect to find a specific obstacle based simply on a recently completed prior run (except those runs whose purpose is to analyze the value of familiarity; in those cases, a specific run may be initiated to allow the pilot to become very familiar with the flight simulator capabilities). Since pilot availability is always a limiting factor, entire sequences of scenarios must be presented to a given pilot in a short time.

5.2.4 Logs and Parameter Lists

The data collection methods and logbook requirements will be developed before the tests and will be verified during the simulator shakedown tests. The recorded parameters will be stored at an appropriate sample rate (twice per second) and transferred to transportable media, such as high-density diskettes or magnetic tapes, as required for post-test processing. Four sets of parameters are of interest:

- Simulator Operator Log
    - Run sequence number
    - Scenario number
    - Flight regime being flown
    - Visibility, obstructions, etc.

- o Helipad, obstruction and landmark lighting
- o Record of off-nominal conditions experienced during the run

o <u>Test Observer Log</u>

- o Run sequence number
- o Subject pilot number, date and time
- o Procedure under test
- o Events and commentary - turn points, deviations, pilot comments, areas of difficulty, etc.

o <u>Pilot Log</u>

- o Helicopter certification/rating
- o Flight experience by type/hours
- o Private
- o Commercial
- o Airline transport
- o Simulator currency
- o Simulator by type/hour
- o Debriefing

o <u>Recorded Parameter List</u>

- o Run sequence number
- o Time mark
- o Environmental conditions (winds, temperatures, etc.)
- o Aircraft position (X,Y,Z)
- o Aircraft velocity (X,Y,Z)
- o Sensor signals (altimeters, etc.)
- o Course deviations (lateral, vertical)
- o Control and switch positions
- o Control positions (throttle/engine speedlevers, cyclic, collective, etc.)

5.3 DATA REDUCTION AND ANALYSIS

The intent of the planned task is to collect, recover, and reduce simulator data to a form useful to analysts. Actual use of this data in the development or analysis of psychological effects, airspace requirements, or target levels of safety will be accomplished in phase two of this project.

Data reduction will center on assessing the influence of variables on pilot performance. By establishing an analytical framework for the evaluation of individual variables, each item can be filtered through a statistical discrimination process. Results will offer a foundational database for objective decisionmaking.

An important factor in this analysis is the variation in performance of subject pilots. Evaluating this element is a paramount issue. Close investigation of "task variance" will further perfect the

decision tool. The effects of variance will be assessed initially by matching "between-subject" variables. Using flight experience as a variable and dividing subject pilots ($S_{\#x}$) into groups on the basis of their flight time (figure 2), provides the between-subject category. The variations in the different simulation runs furnishes the second assessment arena, "across-subject" variables. As shown in figure 2, variables A, B,...N present different scenarios by varying visibility, terrain, or the lighting options. They would be across-subject variables because each would be individually administered to subject pilots. Variance analysis allows us to test the "null hypothesis" for each of the variables. In this hypothetical design, we would be able to substantiate or challenge the effect of individual variables. Does flight experience make a difference when matched against different terrain features? The interaction between variables can be tested and measured. By evaluating mean performance, and the differences between the various interactions, the impact of each treatment can be demonstrated and an associated confidence level provided. Each of the pertinent measures could be subjected to the "analysis of variance," providing usable measures of mental workload and risk.

Pictorial flight-presentation summaries will be plotted and assessed. These will show plan and profile views overlaying a plot of the flight regime involved, as well as its relationship to the obstacles underlying the VFR imaginary surface for each scenario. A plot of track deviation from the ideal course will be developed in the same format (plan and profile) to highlight its relationship to the actual course flown. All presentations will be annotated with time marks to allow correlation of flight control data with the data contained in the operator and observer logs.

Other data recorded as a part of the simulator tests (including primary flight control inputs, navigation control inputs, and instrument flags and warnings) will be plotted versus time for correlation to the graphical data. Statistical analysis of pilot performance factors with regard to the plan and profile views, as well as identification of maximum deviation or deflection events, also will be performed. The results will be presented in tabular and graphical form.

6.0 TEST PLAN SYLLABUS

The test plan is partitioned into two main categories that addresses the technical support and simulation perspectives of the overall syllabus. All subtask definitions and resource estimates in the plan are developed using a "bottom-up" approach.

The test plan syllabus is divided into 15 distinct subtasks. These 15 subtasks are described briefly in the following sections. Appendix A contains a generic timeline of the test plan syllabus to project task completion dates.

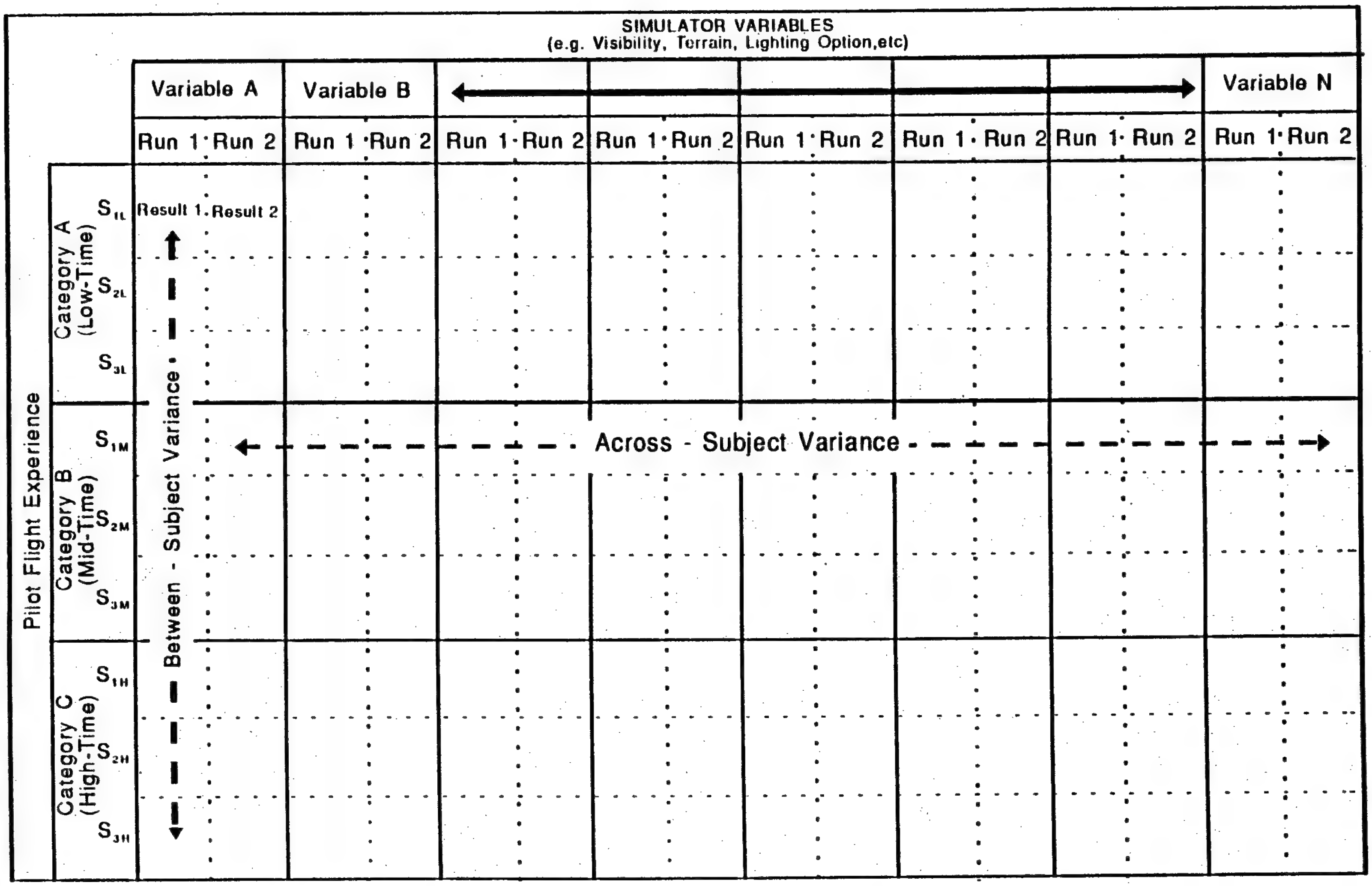


FIGURE 2 SUBSET VARIABLE ASSESSMENT

6.1 TASK START-UP

- o Technical Support Contractor - This is the initial task development for phase two of the simulation program. A statement of work (SOW) and acquisition plan for simulation support services will be assembled for FAA review and approval. The level of detail will be of appropriate depth to complete the required simulation task objectives as defined in phase one.

  Deliverable - Statement of Work (SOW) for simulation support.

  Travel - None.

6.2 REQUEST FOR PROPOSAL (RFP) DEVELOPMENT FOR SIMULATOR SUPPORT

- o Technical Support Contractor - The SOW will be reviewed by the FAA. The results of the review will be used by the support contractor to develop a request for proposal (RFP) to acquire simulation support for the obstacle-rich environment study.

  Deliverable - Request For Proposal (RFP)

  Travel - None.

6.3 SIMULATOR PROPOSAL EVALUATION

- o Technical Support Contractor - The technical support contractor will solicit proposals from qualified simulation services organizations. Initial evaluation will be accomplished by the technical support contractor to determine each proposal's potential. Results in the form of a priority list of competitors will be submitted to the FAA with a recommendation for final selection and contract award.

  Deliverable - Technical evaluation report of proposal submittal.

  Travel - Travel to simulation facilities will be required to assess bid proposals. Team composition should be limited to primary engineer/analyst. Three working days will be necessary at each facility.

6.4 SIMULATOR CONTRACT AWARD

- o Technical Support Contractor - Negotiate a subcontract with the selected simulator support supplier. Areas of negotiation include statement of work, scope of work, resource requirements, schedules, and cost.

  Deliverable - Negotiated subcontract for simulation services.

Travel - As required to prospective simulation subcontractor's facility for negotiation.

6.5 SIMULATION SCENARIO SPECIFICATIONS

- o Technical Support Contractor - Review of simulation technology will be necessary at this point to ensure that scenario strategy parallels simulation contractor capabilities. The technical support contractor must expand on the basic scenario provided in the draft test plan and the pilot briefing material. A syllabus will be developed to support each scenario in the simulation test plan. Each syllabus will include descriptive and visual specifications needed to assure that the scenario supports program objectives.

  Deliverable - Simulation scenario specifications.

  Travel - As required, for coordination of scenario specifications with the simulation subcontractor.

- o Simulation Subcontractor - The technical support contractor will provide the simulation subcontractor with a finalized scenario specification for scenario development. Direct contact between the contractors and the FAA program manager is essential to maintain task focus.

  Deliverable - Preliminary and final scenario programs.

  Travel - None.

6.6 PILOT QUESTIONNAIRES

- o Technical Support Contractor - After review of the scenario programs, the support contractor will develop a questionnaire to evaluate pilot performance and visual recognition cues. Direct coordination with the simulation facility is necessary. The central theme will focus on assessing workload versus overload in the execution of normal operational flight requirements. Each task assessment will concentrate on human factors issues with the overall objective being an evaluation of airspace requirements in an obstacle-rich environment.

  Deliverable - Pilot questionnaire.

  Travel - As required to the simulation subcontractor's facility.

- o Simulation Subcontractor - Direct coordination between the support and simulation contractors is essential. Development of the pilot questionnaire must be done in concert with the simulation facility. This will ensure all levels of the simulation projects are assessed and evaluated.

Deliverable - Review and approval of pilot questionnaire.

Travel - As required to the technical support contractor's facility.

6.7 VISUAL SCENE DATABASES

- Technical Support Contractor - Based on scenario development strategy, the associated visual database will be designed to programmatically vary obstacle density. The technical support contractor will guide and assist simulation engineers in the development of a visual scene database.

  Deliverable - None.

  Travel - Travel to the simulation facility will be required. Team composition should be limited to primary engineers/analysts. No more that five working days should be necessary.

- Simulation Subcontractor - The simulation contractor will be the principal force behind developing the visual scenes for the VFR obstacle-rich scene environment. Correlation between the task initiative and scene development programs must be maintained. Various review stages are required to keep task progression focused to the program objectives.

  Deliverable - Visual scene database.

  Travel - None.

6.8 FAA PRE-TEST REVIEW AND EVALUATION

- Technical Support Contractor - Initial simulation project development review will occur. Preliminary results will be demonstrated to the FAA program manager. A status report outlining progress and accomplishments to date will be presented. Both the technical support contractor and the simulation subcontractor will be given sufficient lead time to assess FAA comments before the review meeting. All concerned parties will review FAA evaluation of task progress, direction, and status.

  Deliverable - Program review.

  Travel - Travel to the simulation subcontractor's facility to support the review meeting.

- Simulation Subcontractor - The simulation subcontractor will support the program review and prepare simulator demonstrations as required to support the review.

  Deliverable - Simulator demonstrations to support the program review.

Travel - None.

6.9 SUBJECT PILOT SCHEDULING

- Technical Support Contractor - In concert with the scenario specifications, the pilot scheduling format will be expanded beyond the initial framework provided in the pilot briefing material. This task will be performed primarily by the simulation subcontractor with support and direction from the technical support contractor. When initiating amendments or modifications, the technical support contractor must be attuned to the simulation subcontractor's facility schedule.

  Deliverable - None.

  Travel - Once the simulation portion of the test plan begins, a representative of the technical support contractor will be in-place at the simulation facility. This individual will remain at the simulation facility throughout data collection and data analysis tasks.

- Simulation Subcontractor - Based on the pilot briefing material, the simulation subcontractor will develop a pilot and simulator schedule to execute the simulation tasks. Subject pilots will be provided by the simulation facility. Both the FAA and the technical support contractor will review, nominate, and approve pilot candidates.

  Deliverable - Visual simulation and pilot schedule.

  Travel - None.

6.10 SUBJECT PILOT SIMULATION EVALUATION (FIRST TEST PHASE)

- Technical Support Contractor - The simulation event will be divided into two separate test phases. The first test phase will establish the initial direction and course of action. The second test phase will consist of adjustments and refinements based on preliminary data assessment results from the first phase. The technical support contractor will actively participate as a technical observer and provide a human factors engineer during simulation runs and data assessment. The technical support contractor will have overall responsibility for task direction and alignment as necessary.

  Deliverable - None.

  Travel - As stated previously, technical support personnel will be in-place at the simulation facility throughout the test phase of the program.

- Simulation Subcontractor - During the first test phase of simulation, the simulation subcontractor will actively execute the test plan. The subcontractor will keep all parties appraised of task performance and offer constructive evaluations.

  <u>Deliverable</u> - Test logs and data from the first test phase.

  <u>Travel</u> - None.

6.11 DATABASE CHANGES

- Technical Support Contractor - Preliminary results of the first test phase of simulation will be briefed to the FAA program manager. The briefing will include a status report of initial simulation efforts and preliminary conclusions. An evaluation of visual scene and data collection revisions needed to fine tune or readjust simulation project direction will be highlighted.

  <u>Deliverable</u> - Briefing of first pilot simulation evaluation.

  <u>Travel</u> - The briefing should be scheduled at the simulation facility. This will provide an opportunity for all parties to visually assess the simulation and recommended changes. The technical support contractor will require key personnel to attend.

- Simulation Subcontractor - Preliminary results from the first test phase will be weighed against requirements. Appropriate modifications to the scenario and questionnaires will be included in the second test phase programming. Active tracking of scenario and test plan adjustments will be maintained. Changes to visual scenes and data collection parameters will be documented. A brief description of necessary changes, if any, will be provided to the technical support contractor along with an assessment of resource and schedule impacts.

  <u>Deliverable</u> - Description of proposed changes to the tests with an assessment of schedule and resource impacts.

  <u>Travel</u> - None.

6.12 SCENARIO REFINEMENTS

- Technical Support Contractor - Proposed changes to the test scenarios provided by the simulation subcontractor will be reviewed by the support contractor. The technical support contractor will review the proposed changes and make necessary recommendations to the FAA program manager. Final refinements will be approved and reprogramming accomplished.

  <u>Deliverable</u> - Recommended changes to the test scenarios.

Travel - Once the proposed changes to the scenarios have been approved, a representative of the technical support contractor will be in-place at the simulation facility. This individual will remain at the simulation facility throughout the second test phase simulation and data analysis.

- Simulation Subcontractor - Each scenario scene will be modified as approved to update the VFR obstacle-rich environment program requirements. Preliminary testing must validate changes and match test runs with task objectives.

  Deliverable - Modified test scenarios.

  Travel - None.

6.13 SUBJECT PILOT SIMULATION EVALUATION (SECOND TEST PHASE)

- Technical Support Contractor - The support contractor will actively participate as a technical observer and provide a human factors engineer during the second half of the simulation runs and data assessment. The technical support contractor will have overall responsibility for task direction and alignment as necessary.

  Deliverable - None.

  Travel - As stated previously, technical support personnel will be in-place at the simulation facility throughout the test phase of the program.

- Simulation Subcontractor - In coordination with the test plan timeline schedule, a precise simulation program will be maintained. The simulation subcontractor will keep all concerned parties appraised of task performance and offer constructive evaluations.

  Deliverable - Test logs and data for the second test phase.

  Travel - None

6.14 DATA ANALYSIS AND PRESENTATION

- Technical Support Contractor - Based on the initial results, the support contractor will brief the FAA program manager. The briefing should address all facets of the simulation program. Final results compiled after assessment and reduction will be incorporated into a draft technical letter report and a final FAA/industry presentation.

  Deliverables - Initial and final briefing presentations on the results of the entire test program; draft technical report on the results of the testing.

Travel - The preliminary briefing will be conducted at the simulation facility. The final briefing should be scheduled at a central location. Travel will be contingent on the briefing location.

- Simulation Subcontractor - Assistance will be provided to the technical support contractor to detail simulation results. Data assessment and reduction will be the responsibility of the simulation subcontractor. Results will be provided to the support contractor in a preliminary simulation report. Review of briefing material will be required by the simulation contractor to ensure data results are appropriately addressed.

  Deliverable - Preliminary simulation report.

  Travel - Travel to the technical support contractor as required to present the preliminary simulation report.

6.15 FINAL REPORT

- Technical Support Contractor - All information and data gathered during this project will be assembled and documented in a final technical report.

  Deliverable - Final technical report.

  Travel - None

- Simulation Subcontractor - The simulation subcontractor will provide an editorial review of the final technical report before delivery to the FAA program manager. Findings will be presented to the technical support contractor.

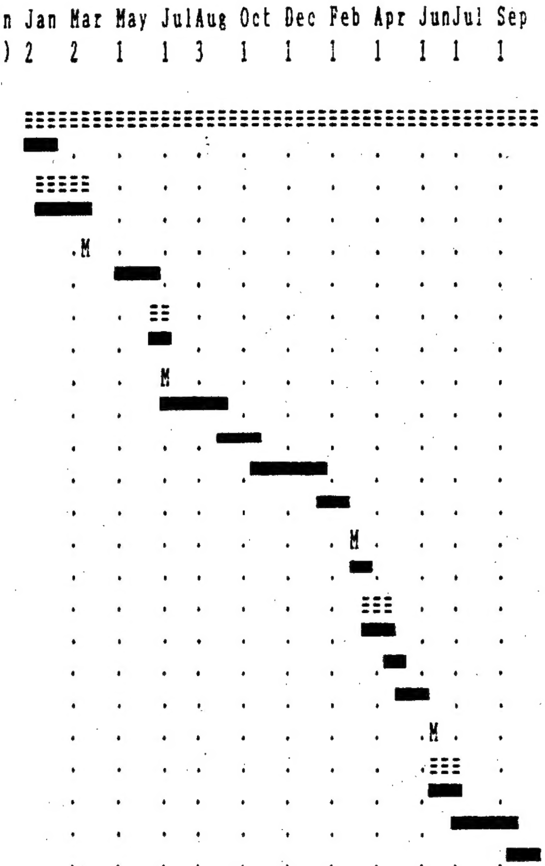
  Deliverable - Preliminary review of final report.

  Travel - Travel to the technical support contractor as required to present the findings.

APPENDIX A
DRAFT TEST PLAN SCHEDULE

Responsible :
As-of Date : 4-Nov   Schedule File : 3BMFDTP2

WBS	Task Name	Start Date	End Date	Duratn (Days)
	Summary	2-Jan	25-Oct	458
Task 1	Task Start-up	2-Jan	5-Feb	25
Task 2	RFP for Simulator Support	17-Jan	20-Mar	45
	RFP for Simulator Support	17-Jan	20-Mar	45
	Issue RFP	23-Mar	23-Mar	0
Task 3	Simulator Proposal Evaluation	4-May	8-Jun	25
Task 4	Simulator Award	9-Jun	29-Jun	15
	Simulator Negotiation	9-Jun	29-Jun	15
	Award	30-Jun	30-Jun	0
Task 5	Simulation Scenarios Specs	30-Jun	9-Sep	50
Task 6	Pilot Questionnaires	10-Sep	14-Oct	25
Task 7	Visual Scene Databases	15-Oct	13-Jan	60
Task 8	FAA Pre-test Review & Eval	14-Jan	11-Feb	20
	FAA Eval/Approval	1-Mar	1-Mar	0
Task 9	Subject Pilot Scheduling	1-Mar	19-Mar	15
Task 10	Subject Pilot Sim Evaluation	22-Mar	9-Apr	15
	(1st Test Phase 1)	22-Mar	9-Apr	15
Task 11	Database Changes	12-Apr	30-Apr	15
Task 12	Scenario Refinement	3-May	28-May	20
	FAA Eval/Approval	15-Jun	15-Jun	0
Task 13	Subject Pilot Sim Evaluation	15-Jun	6-Jul	15
	(2nd Test Phase 1)	15-Jun	6-Jul	15
Task 14	Data Analysis and Presentation	9-Jul	17-Sep	50
Task 15	Final Report	20-Sep	25-Oct	25



Detail Task   Summary Task   Baseline
(Progress)   (Progress)   >>> Conflict
(Slack)   (Slack)   Resource delay
Progress shows Percent Achieved on Actual   M Milestone
Scale: 2 weeks per character

TIME LINE Gantt Chart Report, Strip 1